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Sediment TIEs: Making the Connection

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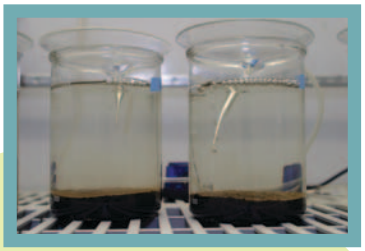
Background

Toxicity testing, also known as bioassay testing, is a common method of assessing whether contaminants present in an environmental sample pose an environmental risk. Methods called **Toxicity Identification Evaluation**, or **TIE,** offer a direct connection between toxicity test results and the cause of the toxicity.

Some specific applications of TIE methods include:

- Assisting in the development of total maximum daily load (TMDL) allocations for water bodies impaired due to sediment toxicity. This would require the identification of chemicals responsible for toxicity.
- Meeting the requirements of a National Pollution Discharge Elimination System (NPDES) permit that would have requirements to investigate the source of any toxicity found during outfall monitoring.

Sediment TIE procedures are an integral part of these types of investigations and one of the primary tools used in the process. (Anderson et al 2007).



Finding the cause of toxicity in any sediment investigation is an important step so that source control and reduction efforts can be directed properly, cost effective clean up standards can be developed, and ultimately the environmental risk posed by the contaminants reduced to an acceptable level.

What is a Toxicity test?

In a toxicity test, marine organisms are exposed to test sediments in the laboratory. A toxicity test indicates the bioavailability of a contaminant, which is the portion of a compound that can pass into an organism. The typical effects that are looked at in a sediment toxicity test include mortality or more subtle biological effects such as reduced growth, impaired reproduction or abnormal development.

Sediment toxicity testing is widely used for compliance with the Washington State Sediment Management Standards (SMS). The common methods used for SMS testing include:

- A 10-day mortality test with the marine amphipod
- A 96-hour larval development test with mussels, oysters or sand dollars
- A 20-day growth test with a marine polychaete worm

One limitation of toxicity testing is that they only tell you if a sample is toxic or not and in certain cases to what degree. This limitation can be mitigated to some extent by conducting simultaneous sampling for toxicity testing and chemical analyses, but still the exact cause of toxicity often is elusive.

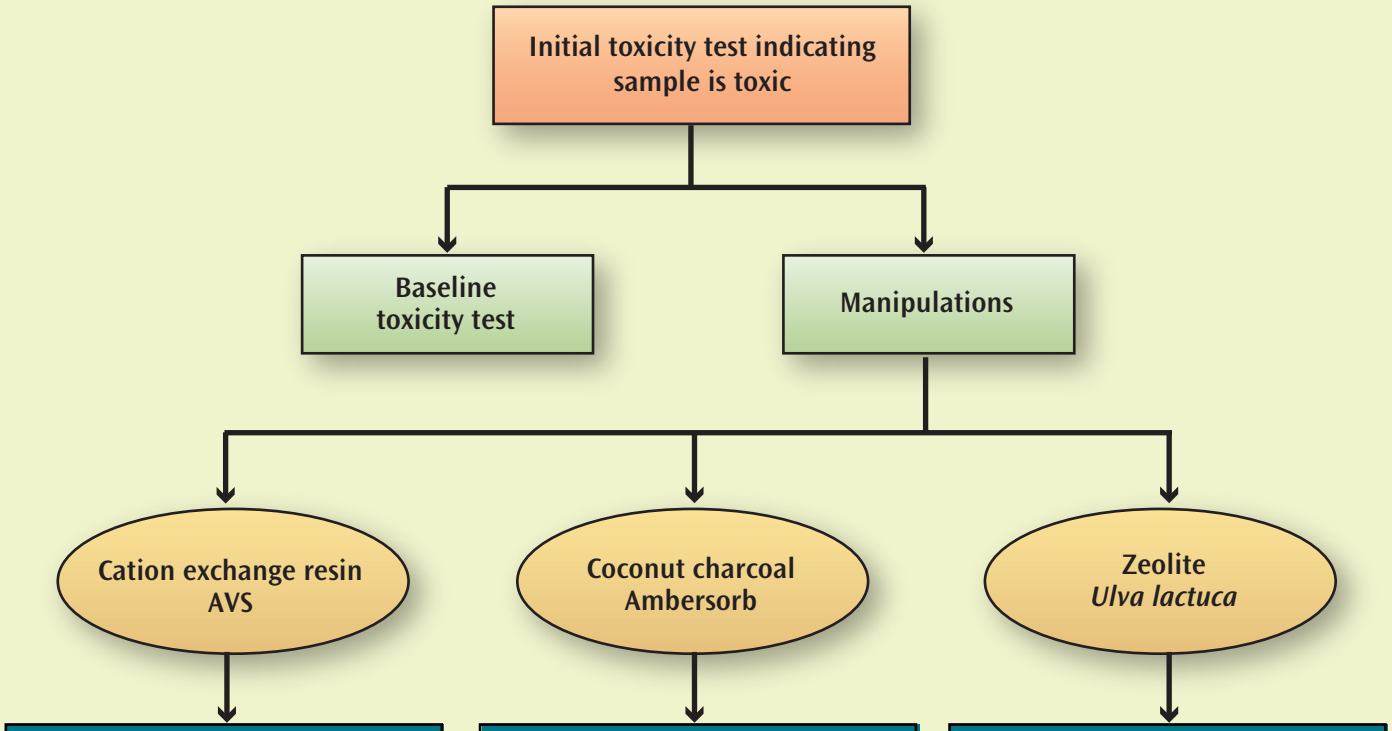
This is due to several factors:

- Unmeasured chemicals may be present,
- Multiple contaminants may correlate to the toxic response,
- These multiple contaminates may have varying degrees of bioavailability,
- The uncertain interactive toxicity of mixtures all add to the challenge of identifying the cause of toxicity (EPA, 2007).

Figure 1:

PHASE I SEDIMENT TIE FLOW CHART

(Adapted from EPA, 2007)



For cationic metals:

- Cation exchange resin addition - a resin designed to form strong associations with specific heavy metals is rinsed in lab water and then introduced to the sediments.
- Acid Volatile Sulfide (AVS) addition - the relationship between Acid Volatile Sulfides and Simultaneously Extracted Metals (SEM) has been studied extensively. AVS in sediments reacts with the SEM, leaving certain metals relatively non-available for uptake by the test organisms. In this manipulation sulfide is spiked into the sediment in an attempt to bind bioavailable metals and reduce their toxicity.
- If resin or AVS addition results in reduced toxicity, then it suggests that cationic metals are a source of toxicity.

For non-ionic organics:

- Coconut charcoal addition - coconut charcoal provides a binding site for organic chemicals thereby reducing their toxicity.
- Ambersorb addition - ambersorb is a resin that has been shown to reduce the bioavailability of organic chemicals.
- If either the charcoal or ambersorb additions reduce toxicity then it suggests non-ionic organics are contributing to the observed toxicity.

For ammonia:

- Zeolite addition - an ammonia-absorbing mineral is mixed in with the whole sediment.
- *Ulva lactuta* addition - seaweed is added to the test chambers.
- A reduction in toxicity by either zeolite or *Ulva* is consistent with ammonia toxicity.

The TIE

TIE offers a direct connection between toxicity test results and the cause of the toxicity. Originally developed in the late 1980s and early 1990s to identify the causes of toxicity in industrial and municipal wastewaters, TIE methods have been adapted to sediments.

The basic concept of a TIE is to manipulate a sample in an attempt to change the potency of a toxicant. The biological response of the test organism is used to determine if the sample manipulation successfully altered the toxicant and reduced its potency (EPA, 2007).

A TIE begins with baseline testing to confirm toxicity. Once toxicity is confirmed multiple manipulations are performed targeting different classes of contaminants (organic chemicals, cationic metals and ammonia) in what is referred to as a Phase I TIE (see Figure 1 on previous page).

Test Interpretation and Limitations

Interpretation of a TIE differs from a standard Sediment Management Standards toxicity test where the results are statistically compared to a reference sediment – clean sediment that is similar to the test sediment.

In a TIE, the results of manipulated samples are compared to the baseline sediment toxicity and an appropriate blank sample for each of the manipulations above. When toxicity is removed it suggests that class of chemicals is contributing to the toxicity. Ideally, both manipulations under each chemical class will reduce toxicity and the sediment chemistry will support the same conclusion.

A simplified example would be that both the zeoloite addition and *Ulva* treatment clearly reduce toxicity to amphipods while the sediment chemistry shows ammonia concentrations well above the values reported in the literature as being acutely toxic to amphipods.

The class of contaminants identified by Phase I (characterization) as contributing to toxicity will move on to more focused, confirmatory testing in Phases II (identification) and III (confirmation).

However, contaminated sediments are often complex mixtures, with multiple contaminants possibly contributing to toxicity. This can make the interpretation of the Phase I TIE results a challenge.

There are limitations to the current suite of Phase I manipulations. For example:

- Cation exchange resins can also cross-react with ammonia and endosulfan (EPA, 2007). These resins also won't account for anionic metals such as arsenic and selenium.
- The current suite of Phase I manipulations are not sensitive to dioxin or dioxin-like toxicants. Nor are they sensitive to mercury toxicity (Ho *et al.* 2009).
- On the organics side, PAHs can be problematic and may not respond to the typical Phase I manipulations of coconut charcoal addition (EPA, 2007).

Therefore, knowledge about site conditions is essential to planning and designing a Phase I TIE and non-standard manipulations may be necessary to account for unique site conditions.

A well designed Phase I study developed with knowledge of the unique site conditions can provide a great deal of information of the contaminants contributing to toxicity. This will provide direction for the next steps, but it won't definitively identify a specific chemical. For that, additional levels of identification and confirmatory testing focused on a specific class of chemicals are necessary.

Closing

Finding the cause of toxicity is a significant step in any sediment investigation so that source control and reduction efforts can be directed properly, cost effective clean up standards can be developed, and ultimately the environmental risk posed by the contaminants reduced to an acceptable level.

For more information on this project you may contact Fran Sweeney by phone; 206-684-2358 or by e-mail: Francis.Sweeney@kingcounty.gov

References and Additional Readings

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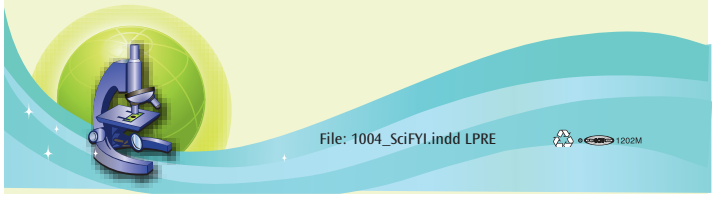

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